INVASIVE SPECIES POSSESS POTENTIAL BENEFITS BASED ON THEIR FALL PHENOLOGY

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ABSTRACT

Phenology is the study of seasonal changes and their relationship to climate, plants, and animals. When looking at native species competing with non-native species, studying plant phenology can be helpful in understanding these plant species in their current environments. These non-native species outcompete native ones, thus changing the ecosystem. Invasive species typically outlive native species, which allows these invaders to continue to spread while the native ones become dormant. Our study was conducted on the Purchase College campus to determine if the phenology of non-native species will progress slower than that of native species on campus, and what species support invertebrates as phenology changes to late fall. Our results show that non-native species phenology changes slower than that of native species. By the end of our observation period, non-native species presented more leaves on branches, showed signs of being less withered, still provided food sources for animals, and the color of the leaves changed minimally compared to native species. Non-native species also provided habitat to about 50% more invertebrates than native species as the climate changed from early to late fall. Overall, the phenology of non-native species does change slower than that of the native species on campus. Additionally, they continue to provide habitat for invertebrates as the weather changes from early to late fall, leading to possible beneficial attributes of invasive species on campus.

Keywords. Guidelines; Phenology, Native Species, Non-native Species, Invertebrates

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INTRODUCTION

Invasive (non-native) species are those that have crossed environmental barriers to disperse in a non-native area and spread their population without any impacts to their survival (Brenton-Rule and Ormsby 2016). Invasive species thrive in non-native areas because they have no natural competition or predators preventing them from decimating the resources in a given area and altering the ecosystems. The biological invasion of these non-natives is an issue seen around the globe. Non-native Nile tilapia (*Oreochromis niloticus*) have invaded Lake Kutubu in Papua New Guinea. The Nile tilapia compete with native fish for food and breeding habitat as well as predation on native fry resulting in a severe population decline of the native fish species populations (Thresher et al. 2020). The non-native zebra mussel (*Dreissena polymorpha*) has widely expanded throughout northern North America, i.e. in The Great Lakes of the United States and Canada (Petsch et al. 2020). Again, the zebra mussel has no native predators in North America as they are from Asia which allows this mussel to thrive without any threat to their population (Petsch et al. 2020). In the meadows of France, invasive Himalayan balsam (*Impatiens glandulifera*) has invaded, altering the agricultural ecosystems, specifically in the Pyrenees (Guillerme et al. 2020).

In order for a species to become invasive, they disperse by crossing environmental barriers. Typically, invasive species are brought to non-native environments by anthropogenic means. The Nile Tilapia swam into Lake Kutubu from over-flooded aquaculture ponds (Thresher et al 2020). The Zebra Mussels in The Great Lakes of the United States, were carried from Asia to the US via the ballast water of ships (Petsch et al. 2020). In terms of invasive plants, the most notable way they cross barriers via anthropogenic means is by physically being brought from one place to another to be used as ornamental plants. The invasive porcelain berry vine (*Ampelopsis glandulosa var. brevipedunculata*) was brought to the United States from Asia because of the fruit it produces and its overall hardiness for survival (Huang and Sherald 2003). Norway maple trees (*Acer Platanoides*) were also brought to the US as ornamental trees. They were wanted for their early budding and late leaf off season making them a hardy and fast-growing tree for ornamental purposes (i.e. shade in parks) (Casey 2013). It was not until these plants were already established and thriving in their non-native environments did scientists see the negative effects they can have on the native ecosystems.

Invasive plants have deleterious effects on the non-native ecosystems for multiple reasons. Invasive plants have long been taking over the environment and research about the effects of them dates far back (the first introduction to the concept being born in 1958 through The Ecology of Invasion by Animals and Plants by Charles Elton). Some of the effects of invasive plants are the alteration of habitat and environmental composition (for example in soil), and the reduction and sometimes even extinction of native species, resulting in “richness reduction” (Powell et al. 2013). This can be a large issue due to their ability to modify soil microbial communities and influence ecosystem dynamics in the environments they invade (Wang 2021). This effect is dangerous as it creates a homogeneity in the environment which then transcends to less diverse habitats and food sources for other species, as well as a threat to the ecosystem. Some characteristics of invasive species include high dispersal, fast growth and reproduction, wider environmental tolerance, use of allelopathy, etc. concluding that invasive species can change ecosystems by altering the resources available (Gordon 1998). These events pressure native species into modifying their composition, possibly leading to the extinction of these species (Gordon 1998). These invasive species use multiple ways of altering environments in addition to their other competitive characteristics, and as a consequence they diminish the presence of native species thus decreasing the biodiversity of the spaces they invade (Gordon 1998; Powell et al. 2013; Hejda et al. 2009). A lack of native diversity is made possible through the various attributes that invasive species possess, which make them more successful in utilizing the primary resources native species need to survive (Gordon 1998).

Weather can play a large role in the adaptability of invasive species in non-native climates. Temperature is one of the abiotic factors that can control the success of an invasive species (Petsch et al. 2020). In the example of the zebra mussels, the cold temperature in the northern North America region allows for the invasive mussel to thrive. The general weather adaptation in combination with the lack of predators aids the mussels in their biological invasion (Petsch et al. 2020). This is also true for plants. We can observe this through the phenological changes in plants. For example, as the weather turns from fall to winter, the ability of a plant to acclimate to colder temperatures relies on its ability to maintain its leaves (Améglio and Charrier 2010). Also, the ability of most plants to flower and produce fruit typically occurs over the spring and summer seasons (Búrquez and Bustamante 2008). Temperature can also affect pollinator activity which could indirectly affect the population of a plant species. For example, if a plant is still producing flowers as the seasons change, that plant’s population will continue to grow versus a plant that cannot acclimate to colder weather and produce flowers (Búrquez and Bustamante 2008).

This sparks the question as to whether or not invasive species only provide negative attributes to the ecosystems they invade. One could speculate that if an invasive species is still flowering and providing food and habitat past the lifecycle of native plant species, maybe these non-native species can provide some benefits to their new environments. For example, the Pacific Oyster (*Crassostrea Gigas*) is a non-native bivalve mollusk to North America. Yet, the dense reefs they form provide habitat for bacteria, which provides food abundance for the bacteria eating invertebrates in these habitats (Chapman 2016). Another example could be the invasive apple snail (*Pomacea Maculata*) in Florida. Although the potential benefits of the non-native snail were not directly discussed in this study, the native Snail Kite (*Rostrhamus Sociabilis Plumbeus*) appeared to only be feasting on this one particular species of snail. These birds even nested in the areas where the invasive snail was most prominent (Cattau et al. 2017). One could argue that the Snail Kite's ability to adapt to eating this new snail species eliminated most competition for food and allowed for food to be more abundant to this population. Of course, more studies need to be conducted on the benefits of invasive species but these few examples show that there is potential for benefits.

There have not been many studies conducted on the phenological differences between native and invasive species in a given area. Purchase College campus is overridden with invasive plant species. Some of the most prominent non-native species seen in these areas are *Artemisia vulgaris* (mugwort), *Ampelopsis glandulosa var. brevipedunculata* (Porcelain berry vine) and *Polygonum Cuspidatum* (japanese knotweed) to name a few. These non-native plants compete with natives for resources such as sunlight and soil (Westbrooks 1998). Because of that, we know that invasive plants are a threat to the environment and ecosystem diversity (Powell et al. 2013; Hejda et al. 2009). They hold various characteristics that make them more resistant to different non-native conditions and habitats (Gordon 1998). This is because invasive species tend to maintain their leaves through harsher conditions than native species. (O'Connell and Savage 2020; Maynard-Bean et al. 2020). However, if these non-native species continue to provide food and habitat longer than the native species we observed, they could possibly provide some benefits to the ecosystems on campus. The goal of our study was to observe phenological traits of non-native species on Purchase College, State University of New York (SUNY) campus to determine if the phenology of non-native species progressed faster or slower than native species on campus and if those species continued to provide habitat to invertebrates.

METHODS

Experiment setup. Our study was conducted at various sites on Purchase College campus (Fig. 1) between October 18th and October 29th. In total we collected data from 11 different species, 5 invasive and 6 native, with 2 replicates of data for each species. We made sure to collect a variety of species in order to diversify our data and make for a sturdier analysis and conclusion. We researched native and invasive species that had similar attributes to have a more coherent data set to compare. The non-native species we chose to study were mugwort (*Artemisia vulgaris*), porcelain berry (*Ampelopsis glandulosa var. brevipedunculata*), japanese knotweed (*Polygonum cuspidatum*), norway maple (*Acer platanoides*) and callery pear (*Pyrus calleryana*). The native species we chose to study were common goldenrod (*Solidago rugosa*), white wood aster (*Eurybia divaricata*), american pokeweed (*Phytolacca decandra*), northern spicebush (*Lindera benzoin*), sugar maple (*Acer saccharum*) and american beech (*Fagus grandifolia*). We used iNaturalist to help confirm the identification of plant species. In addition to collecting qualitative data from the plant species, we also collected invertebrates from each species.

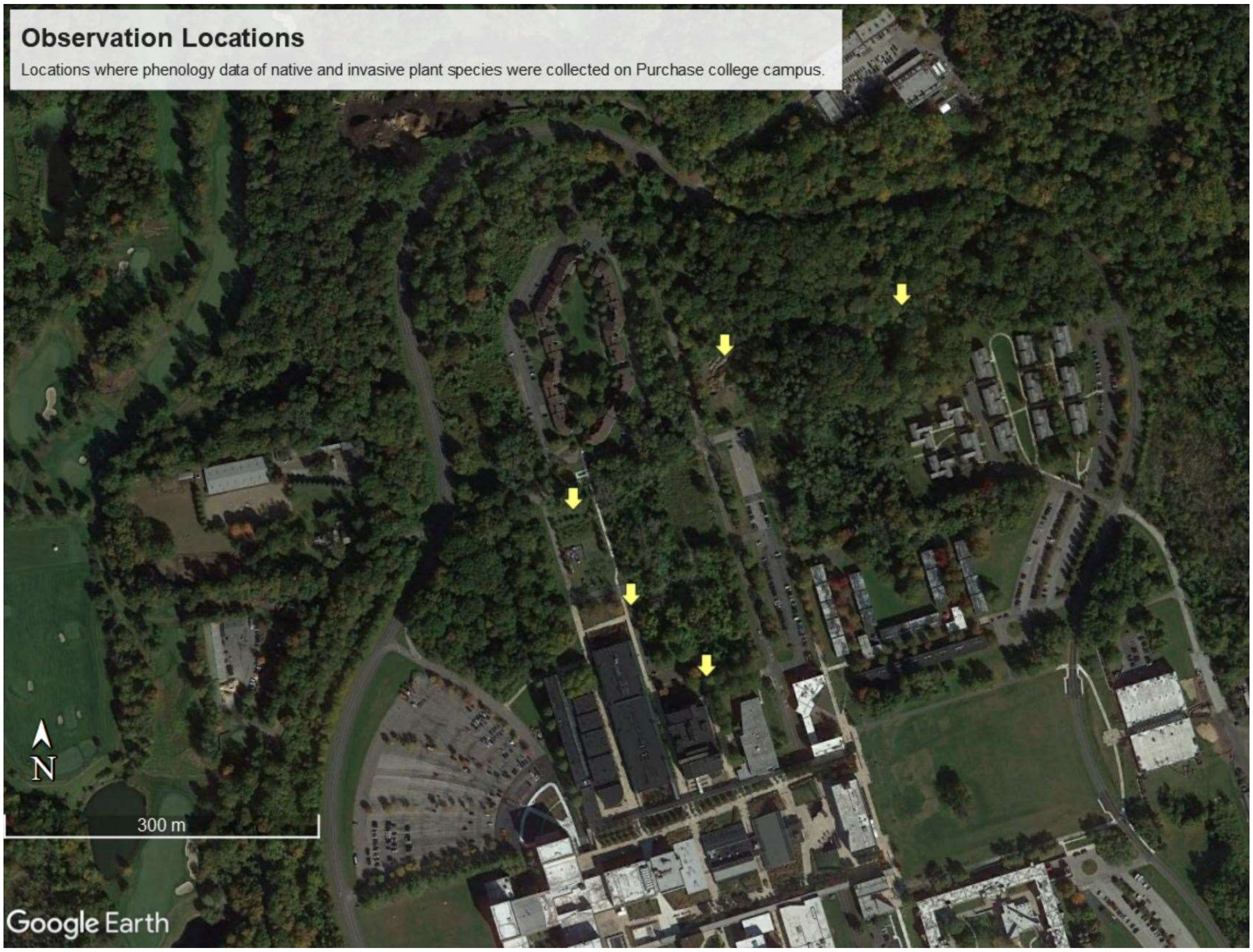

Figure 1. Map of the locations where data was collected on Purchase College campus

Field collection. To collect our data in the field, we used the phone application Budburst to guide us in visually collecting data. With that knowledge we observed the presence of flowers, food sources (fruit or seed), leaves, and invertebrates. We also observed the extent to which the plant or tree was withered on a scale of 1 – None (or no withering) to 5 – All (being fully withered). Furthemore, we observed the color of the leaves as they progressed from green to brown. Green being most alive, yellow being started to wither/die, and brown being all withered/dead. To get these observations for tall trees we used binoculars to analyze these attributes. Our observations were made visually rather than having specific measurements for each category. All of these attributes were then written down in a notebook. We used the camera/phone as a way to take pictures of the plants we were observing and compare the pictures through time. To collect invertebrates, we used a beat sheet and an aspirator for collection. We placed those invertebrates in labeled empty vials and then in a cooler to count the quantity later in the lab.

Data analysis and lab work. When in the lab we input the data and observations noted in the field collection into an excel sheet. The categories on excel were the same as the ones previously mentioned (species, invasive or native, presence of flower, presence of food source, presence of leaves, leaf color, the amount the species withered if at all, and quantity of invertebrates found). We put the current collection of invertebrates in the freezer, and took out the previous collection to count the quantity for our Excel sheet. We continued this process for the rest of our observation period.

RESULTS

Out of the 4 days of observations and data collection, we observed a general phenological trend of invasive species surviving longer through the changing of the seasons than the native species. Overall, there was not too much variation on the availability for food sources. The plants that produced flowers contained a food source up to the point of the flower being fully withered. This appeared to be relatively consistent between both native and invasive species throughout our weeks of observation. The only plants containing a food source by our last day of observation were the invasive Mugwort, Japanese Knotweed, and Callery Pear tree (Table 1). The only native plant to still contain a food source was the Northern Spicebush. This supports our hypothesis that the invasive species would continue to thrive in late fall/early winter (Table 2).

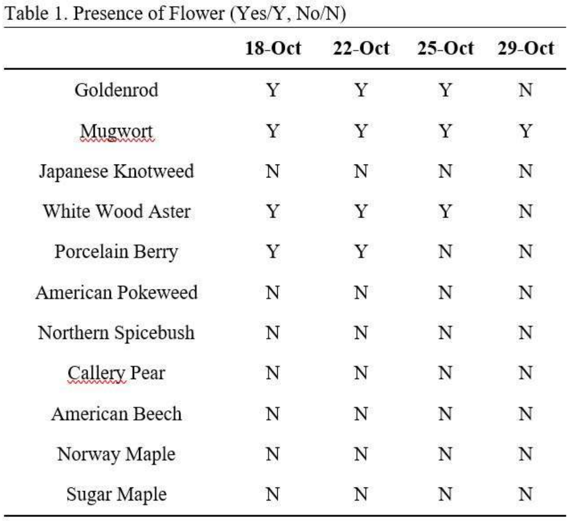

Table 1. Presence of Flower (Yes/Y, No/N)

	18-Oct	22-Oct	25-Oct	29-Oct
Goldenrod	Y	Y	Y	N
Mugwort	Y	Y	Y	Y
Japanese Knotweed	N	N	N	N
White Wood Aster	Y	Y	Y	N
Porcelain Berry	Y	Y	N	N
American Pokeweed	N	N	N	N
Northern Spicebush	N	N	N	N
Callery Pear	N	N	N	N
American Beech	N	N	N	N
Norway Maple	N	N	N	N
Sugar Maple	N	N	N	N

Table 2. Presence of Food Source (Fruit/Seed) (Yes/Y, No/N)

	18-Oct	22-Oct	25-Oct	29-Oct
Goldenrod	Y	Y	Y	N
Mugwort	Y	Y	Y	Y
Japanese Knotweed	Y	Y	N	N
White Wood Aster	Y	Y	N	N
Porcelain Berry	Y	Y	Y	Y
American Pokeweed	Y	N	N	N
Northern Spicebush	Y	Y	Y	Y
Callery Pear	Y	Y	Y	Y
American Beech	N	N	N	N
Norway Maple	N	N	N	N
Sugar Maple	N	N	N	N

Tables 1-2: These tables show if the plant species did or did not have the presence of flower or food source.

As we monitored the progression of leaf off in each species, we observed that the native species of both plants and trees started with fewer leaves overall from day 1 of our observations (Fig. 2.) Invasive species started with most or all of their leaves from day 1 of our observations. Northern Spicebush was the only native plant on day one to contain most of its leaves and ended with most of its leaves on day 4. As you can see, all of the invasive plant species ended with the same level of leaf presence that the native species started with on day 1. By day 4, there was a drastic drop in leaf presence in native plant species as compared to the invasives. We observed the same trend in native and invasive tree species. By day 4 of observations, native trees only had some to few leaves remaining whereas invasive trees had most to some of their leaves remaining.

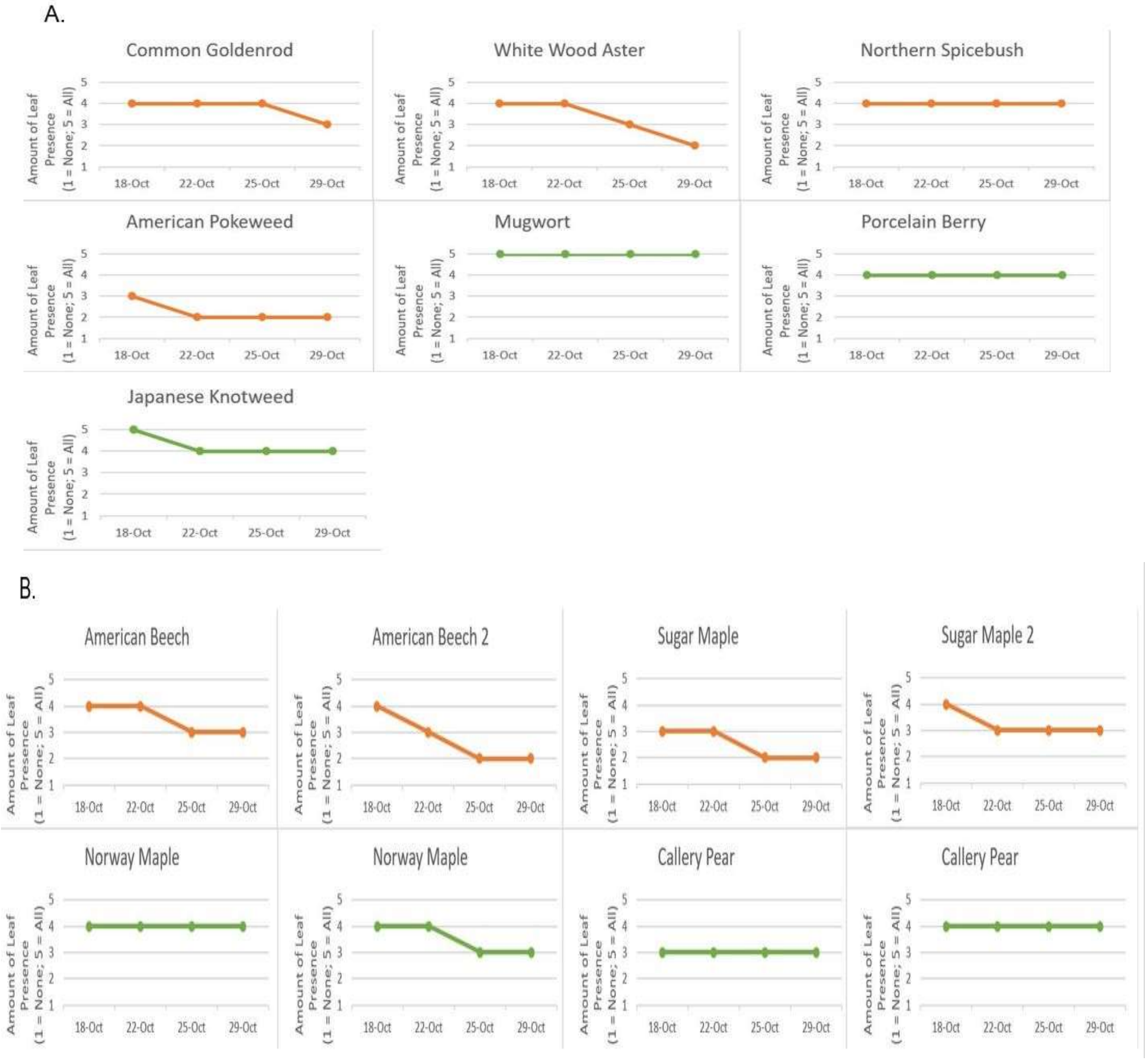

Figure 2 A-B: These graphs show the presence of leaves throughout the observation period in native species as compared to invasive species. Fig 2A. represents shrubs, Native Fig 2B. represents trees. Species. Native species ended the observation with more leaf off than invasive species.

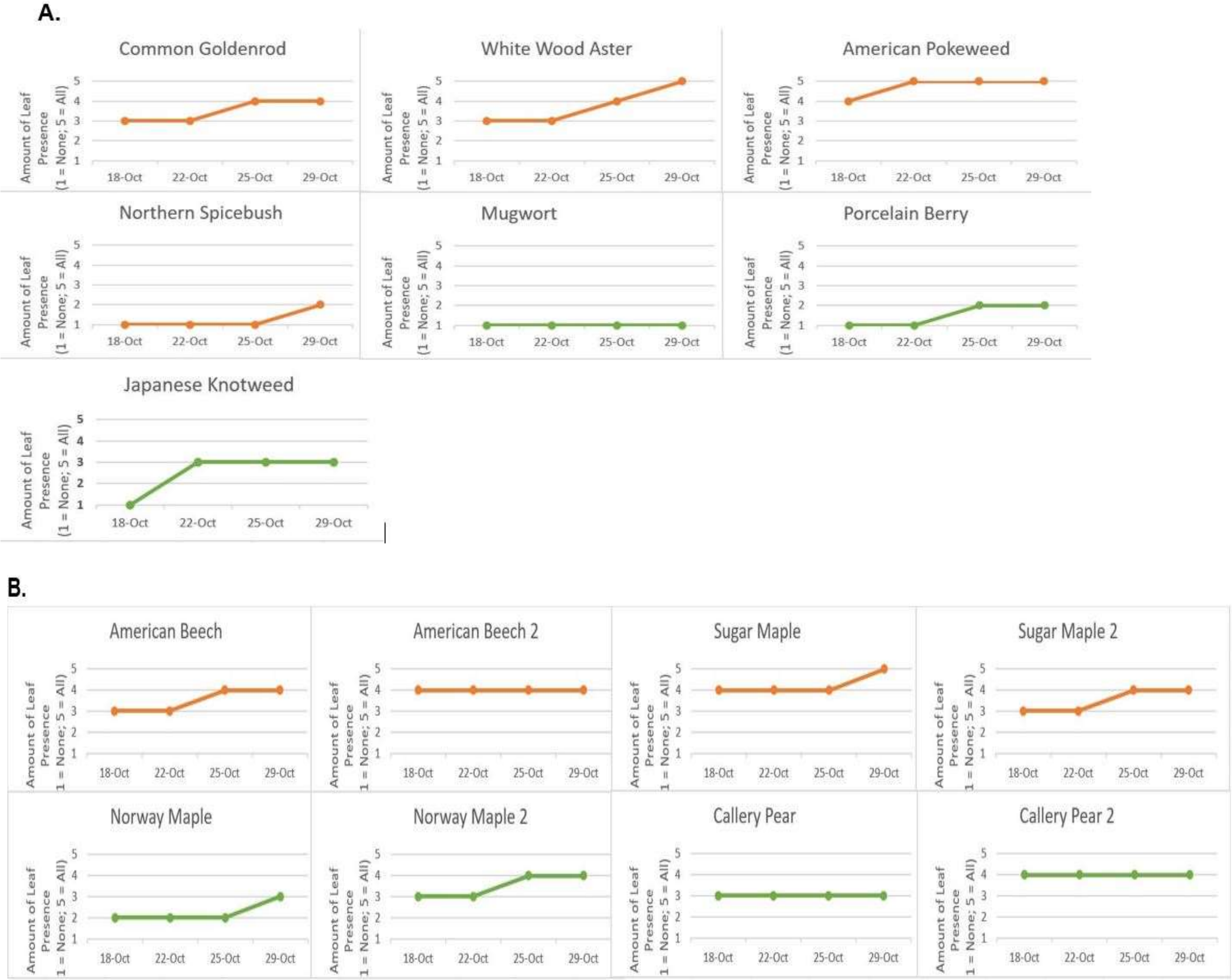

Figure 3: Graphs represent the progression a species had withered while being monitored from Oct 18 through Oct 29. Fig 2A. represents shrubs, Native Fig 2B. represents trees. Species. Invasive species ended the observation period being much less withered than the native species.

The amount a plant or tree was withered did not always correlate to the number of leaves present. For example, American Pokeweed still had leaves remaining even though all of the leaves were completely withered. Overall, as the weeks progressed, the American Beech trees and the Sugar Maple tree leaves were much more withered than the Norway Maple trees & the Callery Pear trees by day 4 (Fig. 3.). The most noticeable difference in the amount of withered-ness between native and invasive species was in the plants. Invasive Japanese Knotweed and Porcelain Berry had very little withering by day 4. Invasive Mugwort was not withered at all. All of the invasive species' leaves remained mostly green throughout the weeks of monitoring. As for the native plants, by day 4 they were mostly or all withered. Except the Native Spicebush just started to experience withering by day 4. The other days of observation Native Spicebush remained completely green and un-withered. Native Goldenrod and Aster slowly started to wither as the weeks progressed. Their leaves also changed from green to green and yellow to yellow the more they withered. American Pokeweed was completely withered and brown from the very start of our observations (Fig. 4.).

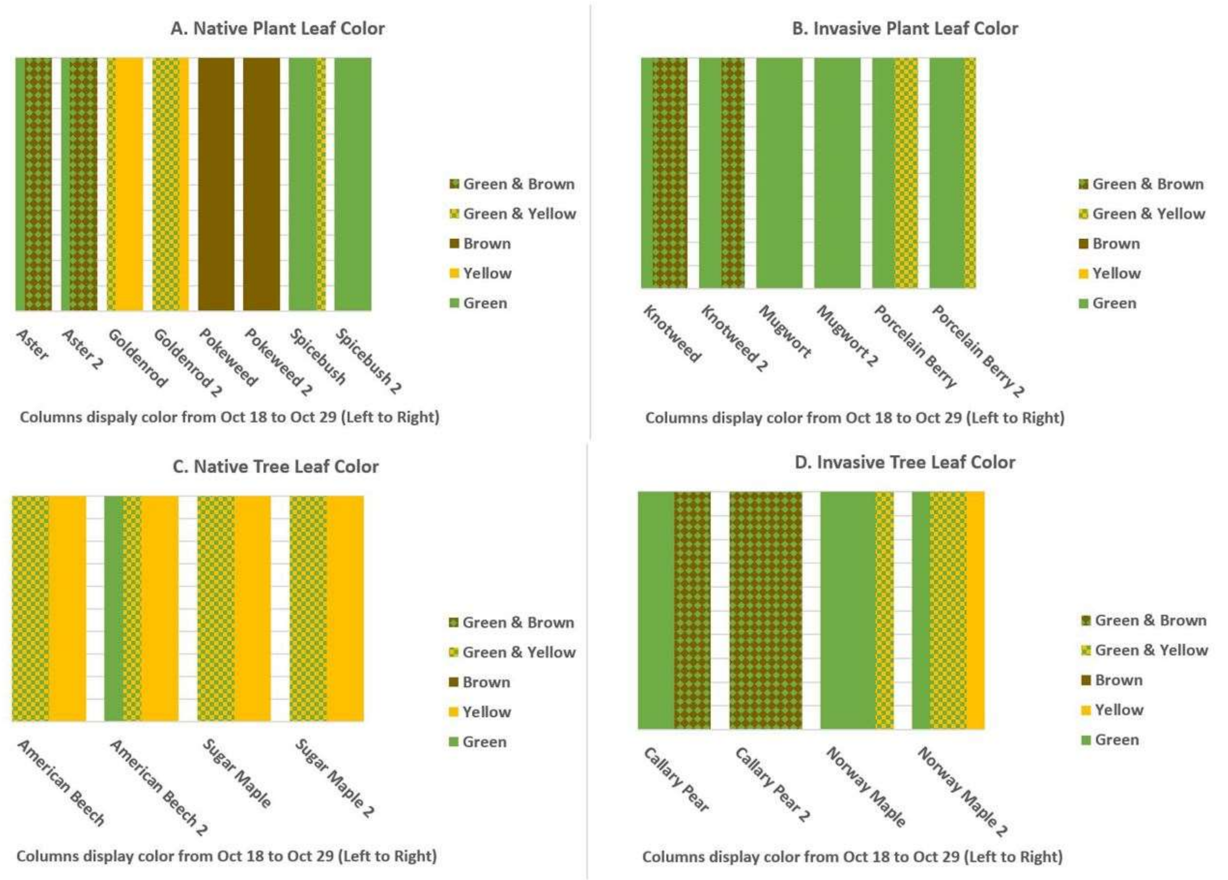

Figure 4: Graphs A-D illustrate the gradual change in leaf color in the native and invasive species observed. All green showing no change in the leaves at all. Green & brown or green & yellow showing some change. All yellow and all brown showing complete change in the color of the leaves.

Throughout our weeks of observing the phenology of native and invasive species, we also monitored the number of insects to determine which type of species was still being utilized by invertebrates as the weeks got colder. The total number of invertebrates found on all native species we observed was 64. The total number of invertebrates found on all invasive species we observed was 120. Overall, the hearty invasive species seemed to be the most utilized (Fig. 5.). Invasive Mugwort was the most favorable plant with a total number of 44. However, Northern Spicebush was the most favorable native plant with a total number of 34, almost equivalent to the second favorite invasive Japanese Knotweed, which has a total number of 35. However, the tree species we observed did not show much variation in invertebrates as it was difficult to find many insects solely on the bark.

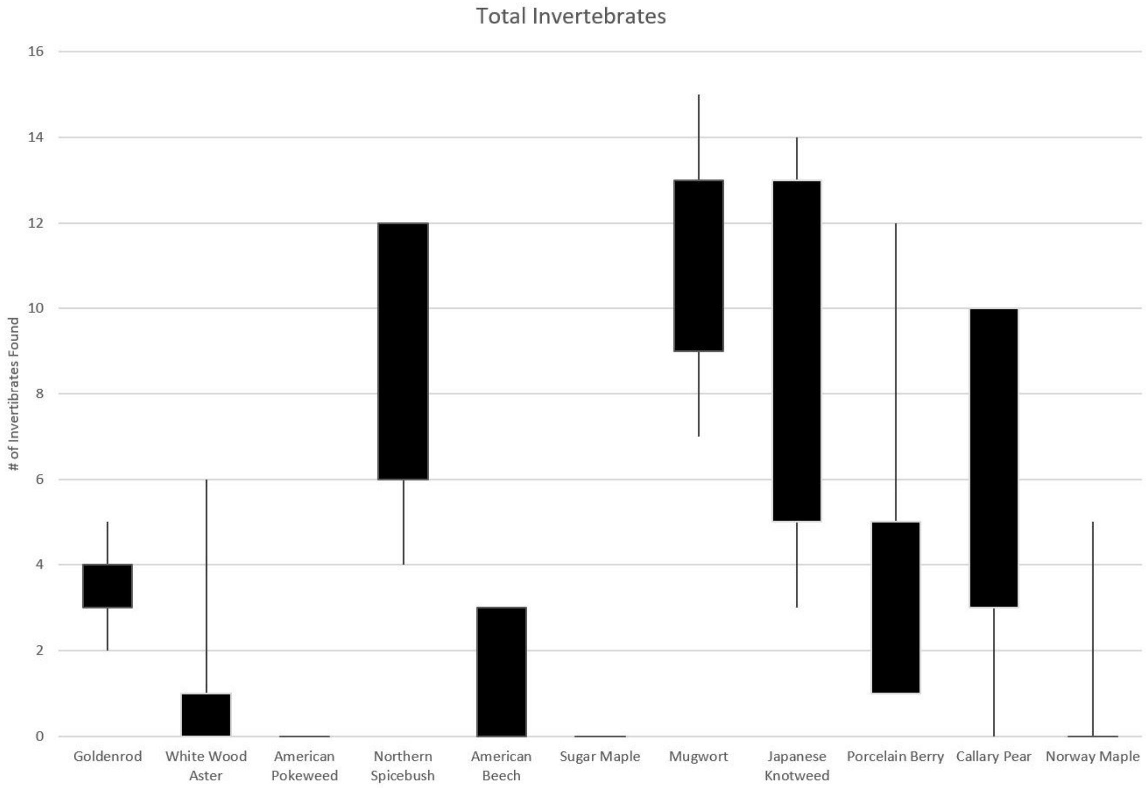

Figure 6: The comparison of the total number of invertebrates found on both native and invasive species. There were many more invertebrates found on invasive species than native species over the course of our observations.

DISCUSSION

Throughout our data collection, we extracted data that seemed to correspond with our hypothesis. It was successful and suggested that invasive plants do out compete in many situations. Although our study would yield greater results with more replicates of data over a longer period of time, our results have supported our hypothesis that the phenology of invasive species progresses slower for early to late fall than native species. The invasive species contained food sources and other resources such as shelter for many invertebrates later in the season. We saw a significantly larger quantity of invertebrates on our invasive plants than our native plants (Fig. 5.). Our research showed that invertebrates are more likely to make habitat selection on non-native plants than native plants, creating large populations in the area. Studies such as this have shown that an abundance of non-native grass can greatly improve insect diversity in a given community (Metcalf 2015).

Unfortunately, our research contained a fair share of inconsistencies. The weather was a factor that affected our data collection. Throughout our observation period, there were weather events such as rain, humidity, and wind. Populations of invertebrates that select habitat in forested areas heavily rely on their host plants for survival and will decline when disturbed by weather related events (i.e rain) (K.J. Gandhi et al 2007). We also hypothesize that weather we experienced affected the quantity of our invertebrate collection among other things. Other things that were not consistent throughout data collection was we did not establish a standard timeframe in which data was required to be collected. Some days we collected data in the afternoon, and other days collected in the early morning. Although the time of day was not consistent every day of collection, there was an even split between afternoons and mornings. There were 2 days we collected data in the afternoon at about 12:30 PM and 2 days we collected data early in the morning at about 9 AM.

Our largest inconsistency was the time we took to collect invertebrates from each species. We did not set a standard amount of time for which we would use our beat sheet at each species. For example, Goldenrod 1 might have had beat sheet collection for 1 minute where Goldenrod 2 might have gotten beat sheet for 2-3 minutes. This affects how much time we allow for invertebrates to fall onto the beat sheet, thus causing a large variation in the number of invertebrates that could have been collected and providing inconsistent data. If we were to recreate this study, there would need to be standards set on data collection days, times, length of times etc. in order to get better samples to best represent the non-native and native species we selected.

When doing a study on the phenology of plants we must consider how climate change may impact those phenological changes. Climate change can affect native species phenology differently from non-natives, potentially causing cascade effects on native populations (Raymundo 2021). This is important because it directly affects how the plants and invertebrates will behave. From early to late fall, we found that the phenological traits of native plant species wither sooner than invasive plants. This suggests that the invasive species we observed have a higher longevity in this non-native environment. Climate change is affecting when seasons change, the average temperature during a given season and the phenological shifts of plants are driven predominantly by climate variability and change (Fitchett et al 2015). One could hypothesize that this gives the advantage to the invasive species as they are more tolerant of these non-native conditions, allowing them to continue growth while native plant populations could decline. For example, some invasive species can be affected by rainfall which can change according to climate changes. Average rainfall conditions will greatly impact the spreading of invasive and native plant species (Raymundo 2021). This could benefit invasive species as it causes more spreading of their species. Furthermore, climate change is affecting the dispersal of invasive and native species. Invasive species, though durable, cannot always withstand the intense effects of climate either. Because of this, it will force native and non-native species to relocate to potentially the same area, forcing competition. Therefore, these invasive species will continue to invade other parts of the non-native ecosystems they have biologically invaded (Wang 2021). This invasion will likely end with invasive species winning the battle against native species.

Initially this study was inspired to observe how climate change affects the phenology on native and non-native plant species. However, because climate change is a very long and ongoing process, a phenology study on climate change needs to be observed over years, with much more data to be collected. The reason for recording data for several years would be to better understand the timeline of climate change. It would also be interesting to perform the same experiments from winter to spring, to observe if bud burst occurs earlier in native or non-native plant species.

CONCLUSIONS

Biological invasions of invasive species to non-native environments have been and will continue to be a growing threat to global ecosystems. However, these species can provide potential benefits to their new environments. Therefore it is important to conduct studies such as phenological trait studies, to further understand if a non-native species is beneficial or harmful to the ecosystem. Especially to protect native plant species as they are pivotal to our native ecosystems. As seasons change from summer to winter, the phenology of plants changes to wither until the next bud burst season. Observing these changes is an important point in the year for native and invasive species, as some will thrive longer than others giving them an advantage to continue to thrive and expand their populations later in the fall season. Our research concluded that the invasive plant species we observed will change phenologically at a slower rate than natives thus providing benefits, such as invertebrate habitat. The reasoning for this is because native plants have changed earlier in the fall. In conclusion, because of their fall phenological traits invasive species may greatly improve insect biomass and biodiversity, even though they pose threats to native plant ecosystems.

ACKNOWLEDGEMENTS

To coffee: for fueling our souls through late night revision sessions. We would also like to acknowledge Oliver Gunderson: a budding entomologist who assisted in invertebrate collection. And of course, thank you to Dr. Jackson for all of your guidance.

AUTHOR CONTRIBUTIONS

Conceptualization (all), Data collecting (all), Data input (all), Data analyzation and organization (JO), Abstract (all), Introduction (JO, SA), Methods (SA), Results (JO), Figures and Tables (JO), Discussion (JL), Conclusion (JL), Editing (all)

LITERATURE CITED

Bustamante, E., and A. Búrquez. 2008. Effects of plant size and weather on the flowering phenology of the organ pipe cactus (*Stenocereus thurberi)*. Annals of Botany 102(6): 1019–1030.

Casey, C. 2013. The Norse Invader. Landscape Architecture Magazine 36–38.

Cattau, Christopher E., Fletcher, Robert J. Jr., Kimball, Rebecca T., Miller, Christine W., Kitchens, Wiley M. 2017. Rapid morphological change of a top predator with the invasion of a novel prey. Nature of Ecology & Evolution. Vol. 2, pages108–115

Chapman, Peter M. 2016. Benefits of Invasive Species. Marine Pollution Bulletin Vol. 107 Issue 1, p1-2. 2p. DOI: 10.1016/j.marpolbul.2016.04.067

Charrier, G., and T. Améglio. 2011. The timing of leaf fall affects cold acclimation by interactions with air temperature through water and carbohydrate contents. Environmental and Experimental Botany 72(3): 351–357.

Chicago Botanic Garden. 2021. (Version 1.0.49) [Mobile app]. App Store. Google Play https://budburst.org/the-app

Fitchett, J. M., S. W. Grab, and D. I. Thompson. 2015. Plant Phenology and climate change. Progress in Physical Geography: Earth and Environment 39(4): 460–482.

Gandhi, K. J. K., D. W. Gilmore, S. A. Katovich, W. J. Mattson, J. R. Spence, and S. J. Seybold. 2007. Physical effects of weather events on the abundance and diversity of insects in North American forests. Environmental Reviews 15(NA): 113–152.

Gordon, D. 1998. Effects of Invasive, Non-Indigenous Plant Species on Ecosystem Processes: Lessons from Florida. Ecological Applications. 8. 975-989. 10.2307/2640955.

Guillerme, S., H. Barcet, N. de Munnik, E. Maire, and C. Marais-Sicre. 2020. Evolution of traditional agroforestry landscapes and development of invasive species: Lessons from the pyrenees (France). Sustainability Science 15(5): 1285–1299.

Huang, Q., and J. L. Sherald. 2004. Isolation and phylogenetic analysis of xylella fastidiosa from its invasive alternative host, Porcelain Berry. Current Microbiology 48(1): 73–76.

Martin Hejda, Petr Pyšek, and Vojtěch Jarošík "Impact of Invasive Plants on the Species Richness, Diversity and Composition of Invaded Communities." Journal of Ecology, vol. 97, no. 3, 2009, pp. 393–403. Crossref, doi:10.1111/j.1365-2745.2009.01480.x.

Maynard-Bean, E., M. Kaye, T. Wagner., and E. P. Burkhart. 2020. Citizen scientists record novel leaf phenology of invasive shrubs in eastern U.S. forests. Biological Invasions 22(11): 3325–3337.

Metcalf, J.L . 2015. Non-native grass invasion associated with increases in insect diversity in temperate forest understory, Elsevier 69: 105-112

O'Connell, E., and J. Savage. 2020. Extended Leaf Phenology has limited benefits for invasive species growing at northern latitudes. Biological Invasions 22(10): 2957–2974.

Ormsby, M., and E. Brenton-Rule. 2017. Forest Invasions: A review of global instruments to combat invasive alien species in forestry. Springer International, 3355–3364.

Powell, K., J. Chase, and T. Knight. 2013. Invasive Plants Have Scale-Dependent Effects on Diversity by Altering Species-Area Relationships. Science (New York, N.Y.). 339. 316-318. 10.1126/science.1226817.

Raymundo, M. 2021. Annual rainfall variation and dispersal limitation combine to alter invaded plant community diversity, dominance hierarchies and seeding phenology, Climate Change Ecology 2: 1 - 11.

Thresher, R. E., R. Smith, and J. Cutajar. 2020. Optimizing the impacts of an invasive species on the threatened endemic biota of a remote ramsar site: Tilapia (Oreochromis niloticus) in Lake Kutubu, Papua New Guinea. Biological Invasions 22(9): 2661–2670.

Wang, A. 2021. Potential distributional shifts in North America of allelopathic invasive plant species under climate change models, Plant Diversity, ScienceDirect 1: 1-9.

Westbrooks, R. G. 1998. Invasive Plants: Changing the Landscape of America. Federal Interagency Committee for the Management of Noxious and Exotic Weeds.